RESEARCH BULLETIN 1006 MARCH 1968

Hoytville Soils: Their Properties, Distribution, Management and Use

R. L. BLEVINS

L. P. WILDING

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
Wooster, Ohio

CONTENTS

* * * *

AGDEX 500 3-68-3.5M

Hoytville Soils: Their Properties, Distribution, Management and Use

R. L. BLEVINS and L. P. WILDING

INTRODUCTION

This paper incorporates previously unpublished and published data and interpretations relative to the numerous investigations which have been conducted on Hoytville soils. A statistical summary of many physical and chemical properties is included.

Hoytville are deep, dark colored, very poorly drained soils which occur in the Lake Plain Region of northwestern Ohio, northeastern Indiana, and southeastern Michigan (Figure 1). There are approximately 900,000 acres of Hoytville soils in Ohio, 150,000 acres in southeastern Michigan, and a small acreage in northeastern Indiana.

Runoff and internal drainage in these soils are slow and many areas become ponded. The soils are difficult to cultivate because of their fine-textured surface layer which has a narrow moisture range favorable for optimum tillage. However, Hoytville soils are highly productive when drained and properly managed, reflecting their high natural fertility and moisture supplying capacity. Most of the acreage is used extensively for row crops or small grains. Some specialized crops such as sugarbeets and tomatoes are also grown.

Hoytville soils are members of the toposequence which includes the moderately well-drained St. Clair and somewhat poorly drained Nappanee soils (Figure 2), all of which are derived from calcareous silty clay till. Other dark colored, very poorly drained soils associated with Hoytville are Pewamo, Paulding, Latty, and Toledo.

Pewamo soils are developed in glacial till of clay loam texture. They have thicker, darker colored surface horizons than Hoytville soils.

Paulding soils are developed in fine textured lacustrine material (60-70% clay), have higher clay contents throughout their profile, and have lighter colored (10YR 4/1) surface horizons than Hoytville.

Latty soils have lighter colored (10YR 4/1) surface horizons, generally higher clay contents in subsoils (50-60%), and weaker structural development than Hoytville soils. Latty soils are derived from lacustrine sediments.

Toledo soils have surface horizons similar to Hoytville but have a lower sand content (usually less than 5%) throughout the profile. To-

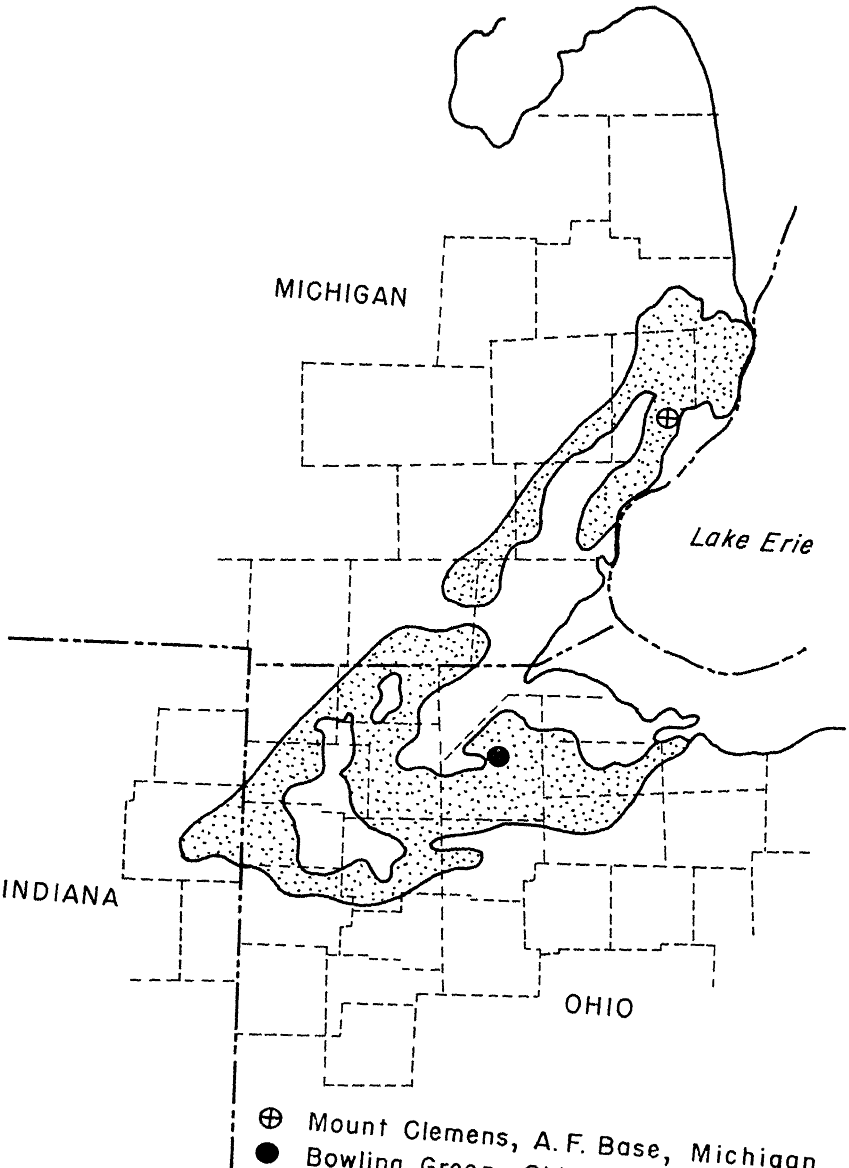

Fig. 1.—Distribution of Hoytville and associated soils.

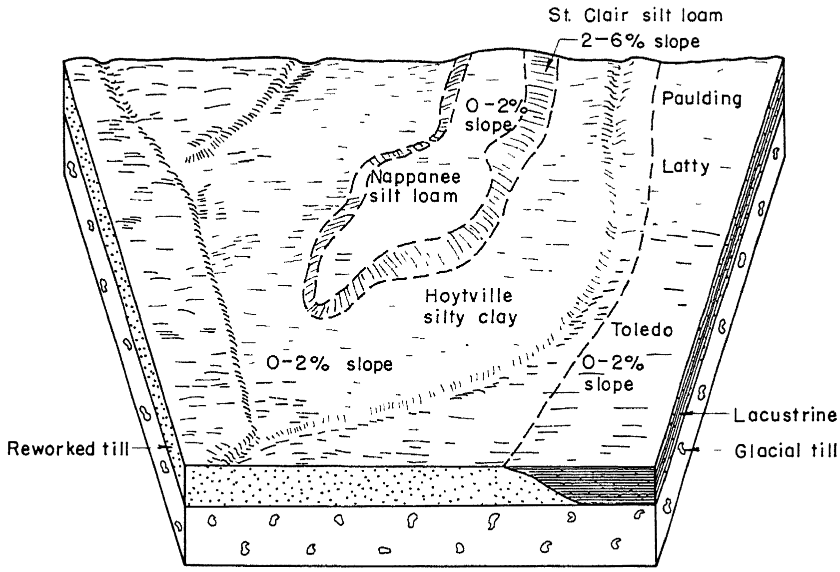

Fig. 2.—Relief and relationship of Hoytville and associated soils.

ledo soils are developed from lacustrine material and thus their parent material contains few or no pebbles. Pebbles and gravel are common in the glacial till C horizons of Hoytville soils.

MORPHOLOGICAL, PHYSICAL, AND CHEMICAL PROPERTIES

Morphology and Classification

The series was established in Paulding County, Ohio, in 1957. Prior to 1952, the Hoytville soils were mapped and correlated in the Brookston series, principally as Brookston clay. The Hoytville soils were formerly classified as a Humic-Gley and tentatively are considered a *Mollic Ochraqualf* in the fine, illitic, mesic family, according to the June 1964 supplement to 7th Approximation (15).

A typical Hoytville soil profile constructed from statistical data has the following properties:

Ap 0-8 inches, very dark gray (10YR 2.9/1.4) silty clay; moderate medium angular blocky structure; firm; pH 6.9.

B21g 8-15 inches, dark gray (1Y 4.3/1.2)* clay with grayish brown (10YR 4.6/4.9) mottles; moderate to strong fine and medium angular blocky structure; very firm; pH 7.1.

B22g 15-27 inches, gray to grayish brown (1Y 4.6/1.5) clay with many yellowish brown (10YR 4.5/5.1) mottles; strong medium angular blocky structure; very firm; pH 7.2.

*1Y hue indicates that the statistical mean falls between 10YR and 2.5Y hues in the Munsell color notation.

TABLE 1.—Mean Monthly Temperature and Precipitation Data for the Northern (Mount Clemens A. F. Base, Michigan) and Southern (Bowling Green, Ohio) Extremities of Hoytville Soil Areas.*

Month	Bowling Green, Ohio Temperature (° F.)	Bowling Green, Ohio Precipitation (inches)	Mount Clemens A. F. Base, Michigan Temperature (° F.)	Mount Clemens A. F. Base, Michigan Precipitation (inches)
January	28.3	2.13	25.7	1.73
February	29.4	1.73	25.8	1.96
March	37.2	2.55	33.5	2.16
April	49.2	3.20	45.8	2.62
May	60.5	3.58	57.1	3.09
June	70.6	3 77	67.6	2.74
July	74.6	3.22	72.8	2.22
August	72.8	2 70	71.2	2.56
September	65.9	2.71	63.4	2.25
October	54.8	2.49	52.6	2.16
November	41.3	2.10	39.4	1.95
December	30.6	1 81	28.8	1.95
Annual	51.3	31.99	48.8	27.39

*Data for 30-year period, 1931-1960.

B23g 27-42 inches, gray (1Y-2.5Y 5.0/1.3) clay with numerous distinct yellowish brown (10YR 4.9/5.4) mottles; moderate to strong medium angular blocky structure; very firm; ph 7.4.

B3g** 42-45 inches, gray (2.5Y 5.5/1.3) clay with many yellowish brown (10YR 4.8/4.8) mottles; weak medium angular blocky structure; very firm; pH 7.6; weakly calcareous.

C 45+ inches, grayish brown (1Y 5.1/1.8) silty clay with dark yellowish brown (10YR 4.3/5.7) mottles; nearly massive; compact calcareous glacial till.

**In 9 out of 19 profiles summarized, a B3g horizon was recognized.

Climate: The continental climate of this area is characterized by moderately cold winters with considerable snowfall and warm summers with short, hot, humid periods. In the winter, cold air advancing out of Canada brings occasional periods of zero weather. Monthly mean temperature and precipitation data for two weather stations are given in Table 1.

The growing season is long enough for field crops, such as corn and soybeans, with an average frost-free period of 140 to 160 days. The growing season extends from the middle of May to the early part of October.

Approximately half of the average annual precipitation of about 30 inches occurs during the growing season. Excessive rainfall and poor drainage conditions in the spring result in excessive soil moisture problems which hinder tillage. The largest amount of precipitation falls in May and June and a shortage of moisture may develop during August and September.

Vegetation: Original vegetation of the Lake Plain Region where Hoytville soils occur consisted of swamp forest. Elm, ash, and soft maple were common species (6). Scattered throughout the swamp forest were occasional openings and wet areas where sedge and grasses were dominant. Sampson (12) postulated that the swamp forest in northwestern Ohio was preceded by wet prairie vegetation. The high organic content in the surface of these soils may be due in part to these conditions.

Physiography, Relief, and Parent Material: The Hoytville soils are derived from calcareous Wisconsin-age till deposits which are believed to have been reworked and modified by glacial lake waters. They commonly occur in close proximity to the beach ridges and moraines, according to transects made by Baker et al (2).

Moraines in this area were deposited when the ice remained stagnant during glaciation. They are generally oriented in an eastward direction. The first lake level, Lake Maumee I, came into existence when the ice front had receded far enough to the north to uncover a basin whose drainage was blocked to the north by the ice and to the south by the Ohio divide (a land area which separates the north-flowing and south-flowing drainages in Ohio). The beaches of Lake Maumee described by Forsyth (4) characteristically occur at elevations of 800 feet above sea level. A re-advance of the glacier resulted in the formation of Lake Whittlesey. The beaches of Lake Whittlesey at an elevation of 735 feet are prominent in northern Ohio (4).

Radiocarbon dates taken from samples of wood just south of Sandusky, Ohio, give dates of approximately 13,000 years ago (5). Since the ice was still present at its southernmost position (Wisconsin stage) near Chillicothe and Cincinnati about 18,000 years ago as recorded by radiocarbon dates, the glacier apparently required about 4,000 to 5,000 years to disappear from Ohio.

The source of most of the ice (Wisconsin glaciation) as reported by Goldthwait (5) lay northeast of Lake Erie and north of Toronto, perhaps near Lake Simco and the Quebec-Ontario boundary. Between 2% and 25% of pebbles counted in western Ohio till are crystalline quartzites, granites, diorites, and schists which can be found in the Ontario region. Sedimentary rocks found in till are black limestones common to the Ordovician belt north of Toronto.

The relief of Hoytville soils is level to nearly level. They commonly occur on slopes less than 2% (Figure 2). Their nearly level position in a landscape with little differential relief and dissection accounts for the poor surface drainage.

Bulk Density and Moisture Retention

Some physical properties of selected Hoytville soils are presented in Table 2. Bulk density values greater than 1.45 g./cc. generally indicate slow water movement and values greater than 1.65 indicate severely restricted root penetration (3). Density values for the B22g horizon of Hoytville soils suggest slow water movement, while those of the C horizon having values of 1.61 (Table 12) are high enough to expect substantial root penetration restrictions.

Moisture retention percent by volume was obtained by subjecting saturated cores to various air pressures or tensions. For surface hori-

TABLE 2.—Soil Physical Data on Selected Hoytville Soils.

Horizon	Depth	Particle Density g./cc.	Bulk Density g./cc.	Moisture 1/3 atm. % by vol.	Retention 15 atm. % by vol.	Available Moisture in./in.	Aeration Porosity %
(AL-S7), Allen County, Ohio							
Ap	0- 7	2.65	1.31	36	24	.12	8.0
B21g	7-17	2.69	1.45	39	26	.13	5.0
B22g	17-36	2.72	1.50	41	29	.12	1.4
B23g	36-45	2.72	1.50	45	29	.15	1.4
(WD-73), Wood County, Ohio							
Ap	0- 7	2.68	1.23	38	21	.16	7.0
B22g	10-22	2.73	1.54	37	23	.13	2.0
B23g	22-38	2.78	1.60	36	25	.10	2.0
(WD-84), Wood County, Ohio							
Ap	0- 9	2.64	1.31	37	22	.15	7.0
B21g	9-13	2.73	1.45	41	25	.16	3.0
B22g	18-27	2.74	1.54	39	25	.14	2.0
B3g	27-42	2.75	1.60	36	26	.10	2.0

TABLE 3.—Base Saturation Percentage and Exchangeable Calcium-Magnesium Ratio for Hoytville Silty Clay (WD-S9 Wood County, Ohio).*

Horizon	Depth (inches)	Exchangeable Cations (m.e./100 g. soil) H+	Ca++	Mg++	K	Base Saturation (%)	Ca/Mg. Ratio
A1	0-5	—	—	—	—	—	—
A3g	5-8	6.0	23.5	2.9	.40	82	8.1
B1g	8-15	3.8	19.0	3.4	.44	86	5.6
B21g	15-22	2.0	17.1	3.5	.47	93	4.9
B22g	22-32	1.6	15.7	3.1	.45	94	5.0

*Profile WD-84 has essentially the same base status relationship with depth.

zons, the value 37% moisture at 1/3 atmosphere is approximately field capacity and the wilting point (15 atmospheres) is approximately 23%. Available moisture in inches of water per inch of soil was calculated by subtracting the moisture retention percent by volume at 15 atmospheres tension from the moisture percentage at 1/3 atmosphere and dividing the results by 100. The resulting values give a measure of the amount of moisture the Hoytville soils can retain. These values indicate the soil's ability to sustain crops and promote growth during periods of low rainfall. Hoytville soils are rated as medium to high in moisture retention, falling within the range of 0.10 to 0.15 inch per inch.

Aeration (non capillary) porosity is an index of the relative amount of large (>50 μ) pores present. Values for the B22g and underlying horizons in the Hoytville soil suggest a slow rate of water percolation.

Base Saturation and Exchange Characteristics

Base exchange percentage is high for Hoytville soils (Table 3). Data obtained by Schafer and Holowaychuk (13) indicate that base saturation is lowest in the A horizon and increases with depth, approaching 100% in the lower part of the solum. Calcium is the predominant cation in the exchange complex. The Ca/Mg ratio is approximately 8 in the surface horizon and decreases with depth.

Clay Mineralogy

Clay mineralogy data for one profile of Hoytville clay loam from Wood County, Ohio, is given in Table 4. Content of clay minerals is

TABLE 4.—Distribution of Soil Clay Mineral Components in the < 2 μ Fraction Based on X-ray Analyses Supplemented by Differential Thermal Analyses, Cation Exchange Capacity and Specific Surface Area, Expressed in Terms of a Percent Range.*

Horizon	Depth (inches)	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Quartz
			Hoytville Clay Loam (WD-84)				
Ap	0-9	Xu	X	XXX	—	Xl	X
B21g	9-18	XX	—	XXX	—	X	Xu
B22g	18-27	XX	—	XXX	—	X	Xu
B3g	27-42	XX	—	XXX	—	X	X
C	96-108	X	—	XXX	X	Xu	Xl

Legend: — not detectable
X 5-15%
XX 15-35%
XXX > 35%
l Lower limit of range
u Upper limit of range

*Data used in Table 4 consists of unpublished data obtained by the Department of Agronomy, The Ohio State University.

expressed in terms of a percentage range. The data were obtained from X-ray analyses supplemented by differential thermal analyses, cation exchange capacity, and specific surface area.

The illite group of clay minerals was found to be dominant ($>35\%$) in all horizons. These data support the placement of Hoytville soils in the *illitic* family grouping in the 7th Approximation. Montmorillonite, a 2:1 expanding type of clay lattice, was next most abundant in B horizons.

Statistical Summary of Selected Properties

Statistical data for the Hoytville profiles are given in Table 5. Statistics reported include the mean, standard deviation, range, coefficient of variation, and number of observations for each property summarized.

The standard deviation (SD) gives a measure of dispersion of observations about the mean. Assuming a normal distribution of observations, a $\pm$ 1 SD about the mean would include approximately 68% of the observations in the population. The coefficient of variation expresses the degree of dispersion in the data as a percentage of the mean and permits direct comparisons of variability among properties.

For soil properties normally expressed in numerical form, statistical variables were computed for each soil horizon from uncoded data. In case of hue notations for matrix and mottles, the following arbitrary integers were used: 5.0, 7.5, 10, and 12.5 for 5Y, 2.5Y, 10YR, and 7.5YR hues, respectively. Grade of structure was coded by using integers 1, 2, and 3 for weak, moderate, and strong structures, respectively. For size of structure, the integers 1, 2, and 3 were used for fine, medium, and coarse classes.

Data for profiles used in the statistical study were provided by the Ohio Soil Characterization Laboratory, Department of Agronomy, Columbus Ohio. Profile descriptions and laboratory data were available for approximately 51 sites classified as Hoytville at time of sampling. Some of these have been subsequently reclassified as other series because of changes in series concepts over the last 10 to 15 years.

Criteria for screening the profiles included thickness and color of the epipedon, texture of the solum, and texture and character of calcareous C horizons. Nineteen sites, each of which is within the range of the Hoytville series in all of the above properties, were selected from the 51 available sites for this study.

The 19 selected profiles did not include those of competing series such as Pewamo, which were screened out because the epipedon was sufficiently dark and thick (greater than 10 inches) to qualify as a mol-

TABLE 5.—Statistical Summary of Selected Properties of Hoytville Soils.

Property	Statistical Variable*	Horizon					
		Ap	B21g	B22g	B23g	B3g	C
Horizon Thickness, inches	Mean	7.8	6.7	12.0	14.8	10.3	—
	SD	0.6	3.1	6.2	6.7	5.2	—
	Range	7.0-9.0	3.0-16.0	4.0-26.0	6.0-26.0	5.0-20.0	—
	CV	8	45	48	45	51	—
	N	19	19	19	15	10	—
Total Sand (0.05mm.-2mm.) %	Mean	17.7	15.2	14.8	14.2	16.2	18.3
	SD	3.3	3.3	3.0	2.8	2.5	3.8
	Range	10.3-24.0	10.4-22.4	10.2-20.0	9.7-19.6	12.5-21.5	9.1-23.8
	CV	19	21	20	19	15	20
	N	19	19	19	15	13	16
Total Silt (50μ - 2μ) %	Mean	42.4	38.0	36.6	37.9	38.4	40.7
	SD	2.9	3.7	2.0	2.4	1.4	4.1
	Range	38.1-49.9	33.0-48.9	33.8-40.5	35.4-42.6	36.6-40.6	30.5-47.4
	CV	7	10	5	6	4	10
	N	19	19	19	15	13	16
Total Clay ($<2\mu$), %	Mean	40.3	46.7	48.5	47.8	45.1	40.3
	SD	3.9	4.2	3.3	3.3	2.7	3.3
	Range	32.9-49.6	36.6-53.1	41.9-55.7	42.9-54.8	40.8-49.8	35.8-48.7
	CV	10	9	7	7	6	13
	N	19	19	19	15	13	16
Fine Clay ($<0.2\mu$), %	Mean	15.3	18.9	20.4	20.0	17.5	13.2
	SD	5.1	2.6	2.5	2.5	2.7	2.8
	Range	8.2-22.0	15.1-21.7	16.7-23.4	17.6-23.7	14.6-20.5	8.3-16.1
	CV	34	14	12	12	15	21
	N	7	7	7	6	4	6

*SD — Standard deviation
CV — Coefficient of variability in percent.
N — Number of observations

TABLE 5. (Continued)—Statistical Summary of Selected Properties of Hoytville Soils.

Property	Statistical Variable*	Horizon					
		Ap	B21g	B22g	B23g	B3g	C
Grade of	Mean	2.0	2.7	2.7	2 5	1.3	1.2
Structure	SD	0.7	0.5	0.5	0 5	0.5	0.4
(1 = weak, 2 =	Range	1.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	1.0-2.0	1.0-2.0
moderate, 3 = strong)	CV	34	18	18	19	37	37
	N	18	18	19	15	9	5
Size of	Mean	1.9	1.4	1.6	1.8	2.1	2.1
Structure	SD	0.6	0 5	0.4	0 4	0.7	0.6
(1 = fine,	Range	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.5	1.5-3.0	1.5-3.0
2 = medium,	CV	31	36	27	20	33	31
3 = coarse)	N	19	16	19	15	9	5
Soil Color	Mean	9 8	8 8	8 5	8.3	8.1	9 1
(Matrix) Hue	SD	0.6	2.1	2.1	2.2	2.3	1.8
10.0 = 10YR,	Range	7.5-10.0	5.0-10.0	5.0-10.0	5.0-10.0	5.0-10.0	5.0-10.0
7.5 = 2.5Y,	CV	6	24	24	27	28	20
5.0 = 5Y	N	19	19	19	15	13	16
Value	Mean	2.9	4.3	4.6	5.0	5.5	5.1
	SD	0.2	0.4	0.6	0.4	0.8	0.8
	Range	2.0-3.0	4.0-5.0	4.0-6.0	4.0-6.0	4.0-7.0	4.0-7.0
	CV	8	11	12	8	14	17
	N	19	19	19	15	13	16
Chroma	Mean	1.4	1.2	1.5	1.3	1.3	1.8
	SD	0.5	0.4	0.5	0 4	0.5	1.0
	Range	1.0-2 0	1.0-2.0	1.0-2 0	1.0-2.0	1.0-2.0	1.0-4.0
	CV	33	35	34	35	36	54
	N	18	19	19	15	13	16

*SD — Standard deviation
CV — Coefficient of variability in percent.
N — Number of observations

TABLE 5. (Continued)—Statistical Summary of Selected Properties of Hoytville Soils.

Property	Statistical Variable*	Horizon					
		Ap	B21g	B22g	B23g	B3g	C
Soil Color (Mottles) Hue (12.5 = 7.5YR, 10.0 = 10YR, 7.5 = 2.5Y)	Mean	—	10.0	9 9	9.8	10.2	10.0
	SD	—	0.8	0.6	1.1	0 7	0 0
	Range	—	7.5-12.5	7 5-10.0	7.5-12.5	10.0-12 5	—
	CV	—	8	6	12	7	0
	N	—	19	19	15	13	4
Value	Mean	—	4 6	4 5	4 9	4 8	4.3
	SD	—	0.5	0.7	0 5	0.4	0.5
	Range	—	4 0-5.5	3 0-6.0	4.0-6.0	4.0-5.0	4 0-6.0
	CV	—	11	15	10	8	11
	N	—	19	19	15	13	14
Chroma	Mean	—	4 9	5 1	5.4	4.8	5.7
	SD	—	1 4	1 8	1 8	1.6	2.1
	Range	—	3 0-8.0	2 0-8 0	1.0-8.0	1.0-7.0	1 0-8 0
	CV	—	28	36	32	33	36
	N	—	19	19	15	13	14
Ratio Fine Clay to Total Clay	Mean	0 36	0 39	0 41	0.41	0.38	0 32
	SD	0.10	0 04	0 04	0.04	0.03	0 06
	Range	0.23-0.44	0.32-0 44	0.35-0 44	0.35-0.46	0 35-0.41	0.21-0 39
	CV	26	11	9	9	7	19
	N	7	7	7	6	4	6
pH	Mean	6 9	7.1	7 2	7.4	7 6	7.7
	SD	0.4	0.3	0.2	0.2	0 2	0.2
	Range	6 4-7 5	6 1-7 5	6 5-7 6	6 9-7.7	7 2-8 0	7.2-8.0
	CV	5	5	3	3	2	3
	N	19	19	19	15	13	16

*SD — Standard deviation
CV — Coefficient of variability in percent.
N — Number of observations

lic epipedon. Profiles of the Paulding series were screened out due to their lacustrine clay sediment containing 60% or more clay and having a lighter colored (moist values >3.5) epipedon. Profiles of Latty soils were screened out due to their lighter colored surface horizons (generally 10YR4/1, moist) and a general tendency for higher clay contents in the solum. Profiles of Toledo soils were screened out due to the low sand content in their solum (less than 9%) since they developed from lacustrine material.

Profiles not consistent with the following ranges were excluded from this statistical summary (see Appendix I for a listing of profiles utilized in this summary):

1. Epipedons with color values <3.5 not exceeding 10 inches in thickness.
2. Chromas of 2 or less dominant (in 60% of mass) in control section.
3. Clay content of B horizons ranging from 35 to 56%.
4. Sand content in control section ranging from 9 to 25%.
5. Underlying parent material having a clay content ranging from 35-50%.

A summary of selected properties of Hoytville profiles within the current concept of this series are given below. The morphological properties of a typical Hoytville soil profile as constructed from statistical data are presented under the section, Morphology and Classification.

pH: There is very little statistical variation in pH of the Hoytville soils. The profiles investigated have a mean pH value of 6.9 in the Ap horizon. The pH gradually increases with depth to a value of 7.7 in the C horizon. This increase with depth can be attributed to a decrease in degree of leaching due to the fine texture and poor drainage and a resulting high calcium carbonate equivalent of the parent material.

Calcium Carbonate Equivalent: Calcium carbonate equivalents of the B3g and C horizons have a mean of $5.6 \pm 4\%$[1] and $15.3 \pm 5.4\%$, respectively. The high degree of variability in this property is attributed to the variation in intensity and depth of leaching and to inherent carbonate variability. However, it is postulated that if profiles had been sampled to greater depths in the parent till, the variability in calcium carbonate equivalent would have decreased markedly. There was little consistency in the sampling depth of the calcareous C horizons.

Depth of Leaching: Initial field observations of carbonates, or depth of carbonate leaching, showed a mean depth of 41 ± 6 inches.

[1]The $\pm$ value following the mean is 1 (SD) standard deviation and 68% of the observations would be expected to fall within this range.

The range in depth of carbonates observed was 33 to 54 inches. Hoytville, the poorly drained member of the toposequence, has been leached on the average 12-18 inches deeper than the somewhat poorly drained Nappanee or moderately well drained St. Clair members. This probably reflects the greater volume of water leached through this soil because of its nearly level or slightly concave topographic position.

Organic Matter Content: The mean organic matter content of Ap horizon was 6.0 ± 2.1%. The range of organic matter content in the Ap horizon was 3.6 to 13.8%. This value is higher than that of the better drained members of the toposequence, such as the St. Clair soils, which have organic matter contents in Ap horizon of 3 to 4%. The relatively high organic matter content of Hoytville soils supports their earlier classification as Humic-Gley soils.

Particle-Size Distribution: The mean clay content was 40.3 ± 3.9% in Ap horizon, 46.7 ± 4.2% in B21g, 48.5 ± 3.3% in B22g, 47.8 ± 3.3% in B23g, 45.1 ± 2.7% in B3g and 40.3 ± 3.3% in the C horizon. Variability in particle size separates is small, with silt and clay being more uniform than sand content. The sand variation may be due in part to thin lenses of sandy material caused by local sorting of the till by shallow lake waters.

The distribution of 2μ clay with depth is given in Figure 3. Quantitative criteria, as defined in the 7th Approximation (15), were used to establish whether Hoytville soils have an argillic horizon. Since a mean clay content of 40.3% was obtained for the A horizon, both the ratio criterion (B/A) and the absolute increase in clay content from eluvial (Ap) to illuvial (B22g) horizons were used. Both apply only to those sola without parent material discontinuities. A possibility of parent material discontinuity exists in Hoytville soils due to reworking of the till by the action of waves in the old glacial lakes and/or possible loessial admixtures with the surface (18).

The mean ratio of total clay in the illuvial horizon (B22g) to that of the eluvial horizon (Ap) is 1.2 (Table 6). By calculating a combined weighted average of B21g, B22g, and B23g to the clay content of the Ap horizon, a ratio of 1.18 was obtained. There is a mean absolute increase of 8.2% clay from the Ap horizon to the B22g horizon (Table 5). Thus, both criteria for establishing the presence of argillic horizons meet the minimum requirements.

Field descriptions of soil profiles prepared prior to 1960 did not note the presence of clay films. More recent examinations of these soils suggest the possibility of thin patchy, organic clay films coating primary and secondary ped units when observed moist; when dried, clay films become indistinguishable.

The B22g/C clay ratio is 1.20. If the assumption is made that essentially all carbonates are in sand and silt size fractions, as recent data for Celina and Morley soils of Ohio indicate (14), then the clay percentage of the C horizon would be about 15% greater on a carbonate-free basis. Such calculations on a carbonate-free basis yield B/C total clay ratios which approach unity and thus show little evidence of an argillic horizon. On the other hand, the fine ($<0.2\ \mu$) clay fraction increased in B22g and B23g horizons and decreased in the C horizon. This relation also holds when the clay is calculated on a carbonate-free basis. It would seem on this basis that sufficient clay has either been translocated from the overlying horizons or synthesized in situ to constitute an argillic horizon in these soils. Thin section analysis of these soils is needed to positively establish the presence or absence of an argillic horizon.

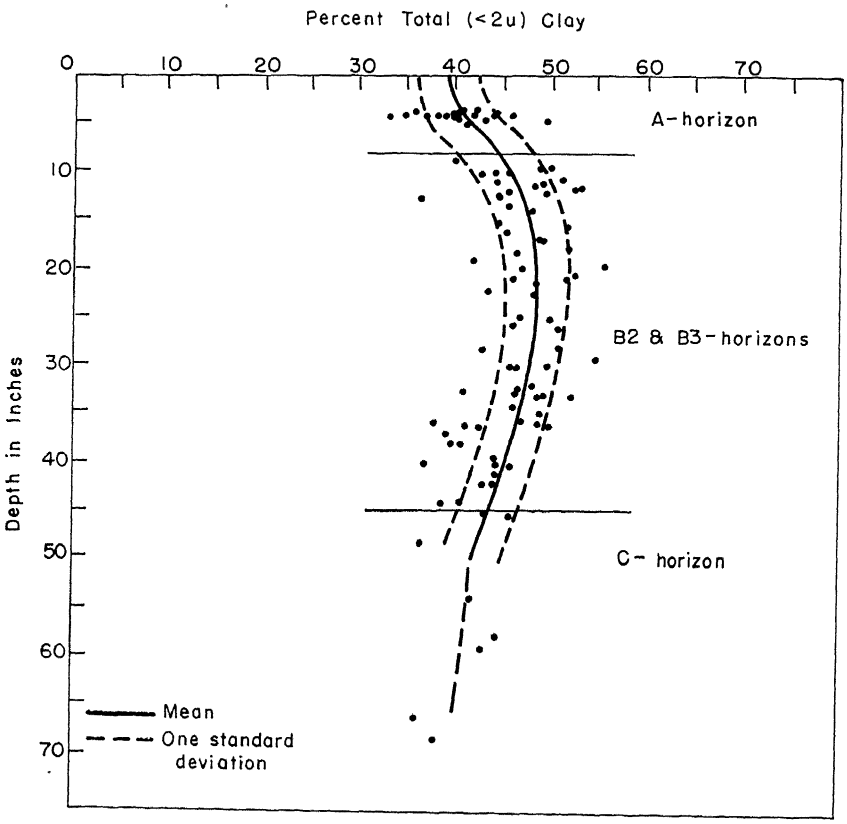

Fig. 3.—Total clay distribution in 19 Hoytville profiles.

TABLE 6.—Organic Matter Content, Calcium Carbonate Equivalent, Initial Field Observation Depth of Carbonates, Solum Thickness, and Ratios of Total Clay Between Horizons.

Property	Statistical Variables				
	Mean	SD	Range	CV	N
Organic Matter, % (Ap horizon)	6.0	2.1	3.6-13.8	3	18
Calcium Carbonate Equivalent, %					
B3g horizons	5.6	4.0	1.6-12.4	71	10
C horizons	15.3	5.4	0.9-21.7	35	14
Depth of Initial Observations of Carbonates by Field Observations (inches)	41.1	6.0	33.0-54.0	15	18
Composited Thickness of B21g, B22g, and B23g Horizons (inches)	31.2	7.8	21.0-46.0	25	19
Thickness of Horizon of Maximum Clay Accumulation (inches)	12.7	6.2	6.0-26.0	43	19
Depth of Horizon of Maximum Clay Accumulation (inches)	14.4	4.6	7.0-24.0	32	19
Maximum Clay Content, %	48.8	3.0	44.5-55.7	6	19
Solum Thickness (inches)	44.9	10.3	35.0-68.0	23	16
Total Clay Ratios ($< 2\mu$)					
B21g/Ap	1.16	0.09	1.0-1.35	8	19
B22g/Ap	1.20	0.08	1.08-1.43	7	19
B23g/Ap	1.19	0.07	1.08-1.32	6	15
B3g/Ap	1.12	0.10	0.95-1.39	9	13
Ap/C	0.98	0.09	0.83-1.22	10	16
B22g/C	1.19	0.10	1.01-1.37	8	16

Grade of Structure: Values for grade of soil structure are moderate to strong, fine to medium angular blocky for the B21g and B22g horizons. The B23g horizon has moderate to strong, medium angular blocky structure and the B3g a weak to moderate, medium angular blocky structure. The structure of the C horizon ranges from weak, medium angular blocky to massive.

Variability in Soil Properties: Large coefficients of variability were obtained for the following soil properties: horizon thickness, organic matter content, chroma notation for soil color, size and grade of structure, and calcium carbonate equivalent. Those properties which are less variable include hue and value variables of color, silt and clay content, pH, depth of leaching of free carbonates, and clay ratios between different horizons.

The variability of Hoytville soil properties is closely related to that reported by Wilding et al (19, 20) for Miami and Morley toposequences. Hoytville soils exhibited a smaller degree of variability for pH than Blount and Morley soils. They also had a somewhat lower coefficient of variability for clay and silt content. On the other hand, they showed a higher degree of variation for horizon thickness and calcium carbonate equivalent.

USE AND MANAGEMENT

Fertility

The Hoytville soils, as reported by Pratt and Morse (11), show high exchangeable K and very high K release. They concluded that the need for K fertilization of crops grown on these soils under favorable conditions is extremely small. Potassium release values are sufficiently high that exchangeable K absorbed each year by crops should be rapidly replenished by K release. However, they concluded that under conditions of poor structure and restricted aeration, there is need for K fertilization.

Studies by McLean and Simon (9) support the above work and demonstrate no consistent response to K fertilization. Potassium release values of Hoytville soils were as high as 1560 lb./A. and exchangeable K as high as 464 lb./A. In the same studies, however, Hoytville soils responded positively to additional nitrogen amendments.

In a summary of the fertility status of Ohio soils by Jones and Musgrave (8), phosphorus and potassium fertility levels are presented for a large number of Hoytville soils (Tables 7 and 8). The percentage of Hoytville soils testing high for potassium decreased slightly from the period 1956 to 1961. This may suggest a slow depletion of mineral and/or fixed K due to intensive cropping. More recent soil test data and recommendations further emphasize the probable need for K fertilization for optimum crop yield on these soils. Phosphorus levels seemed to remain about the same for the period 1956 to 1961, ranging from medium to high. In recent years, responses to manganese applications have been obtained with soybeans.

Estimated Crop Yields

Yields given in Table 9 are for two levels of management, high and average, and are based on averages for 10 years, 1954-1963. High level

TABLE 7.—General Fertility Level of Hoytville Soils Tested in Ohio, 1961.*

Soil	Number of Samples	Potassium Mode lb./A.	Potassium Median lb./A.	Phosphorus Mode lb./A.	Phosphorus Median lb./A.	Lime Required None %	Lime Required 2 T./A. %
Hoytville	4,360	360	265	18	31	26	17

*Data were previously published by Jones, J. Benton, Jr. and O. L. Musgrave. 1963. Fertility status of Ohio soils as shown by soil tests in 1961. Ohio Agri. Exp. Sta., Res. Circ. 118.

TABLE 8.—Percent of Hoytville Soils Either Low, Medium, or High in Phosphorus and Potassium as Determined by Soil Test in Ohio, 1961.*

Soil	Number of Samples	Phosphorus L	Phosphorus M	Phosphorus H	Potassium L	Potassium M	Potassium H
Hoytville	4,360	8	46	44	2	12	86

*Data were previously published by Jones, J. Benton, Jr. and O. L. Musgrave. 1963. Fertility status of Ohio soils as shown by soil tests in 1961. Ohio Agri. Exp. Sta., Res. Circ. 118.

TABLE 9.—Crop Yields on Hoytville Soils.*

Crop	Average Yield (bu.)	High Yield (bu.)
Corn	73	102
Oats	55	80
Winter Wheat	32	42
Soybeans	27	36
	(tons)	(tons)
Sugarbeets	14	18
Alfalfa-Mixed Hay	3	4.2
Alfalfa-Mixed Pasture	2.4	3.3
Bluegrass	90 (A.U. days)	—
Tomatoes		25.2**

*Data for this table taken from North Central Regional Publication 166.

**Average yields for 1963, 1964, and 1965 for Tecumseh variety tested at Northwestern Branch, OARDC, Hoytville, Ohio.

TABLE 10.—Effect of Tillage Practices on Corn Yield and Percent Stand.

Plowing		Yield (bu./A)	Percent Stand
	Previous Ciop, Sod		
Fall		110	100
Spring		99	84
	Pievious Crop, Corn		
Fall		102	100
Spring (early)		90	81
No Plowing		99	100
Spring (late)		69	91

LSD = 5 bu. at .95% confidence level

yields include optimum application of management practices, such as adequate surface and internal drainage, optimum tillage, planting adapted crop varieties, optimum plant populations, and controlling weeds and diseases. High levels of management also include efficient use of crop residues and green manure crops to maintain organic matter level and facilitate production of nitrogen.

Average yields represent the means for all types of farm management levels over a 10-year period. Data from the Statistical Reporting Service, U. S. Dept. of Agriculture, were used to estimate average crop yields. Average management levels included use of fertilizer but often the applications were inadequate. Cropping systems, plant populations, and soil physical conditions were often below optimum levels. Average yields are probably a better guide for agricultural land evaluation since they reflect to a lesser degree the ability of the farm manager or supervisor.

Influence of Methods of Tillage on Crop Yields[2]

Studies are being conducted on Hoytville soils to evaluate methods of tillage. Although a greater number of years of sampling is desired before attempting to make conclusive evaluations, results from 5 years of sampling are presented in Table 10.

Recommended tillage practices on these soils are fall plowing or no plowing if weeds are not a problem. Early spring plowing may be a suitable practice if the soil dries out early enough. Late spring plowing resulted in later planting dates and significant yield reductions.

[2]Unpublished data from the Ohio Agricultural Research and Development Center on research conducted by G. B. Triplett, Jr. and D. M. Van Doren, Jr. from 1960-1965.

Engineering Properties of Hoytville Soils

Certain soil properties are of special interest to engineers because they affect construction and maintenance of non-agricultural facilities, such as roads, airports, pipelines, building foundations, drainage systems, and sewage disposal systems. The U. S. Bureau of Public Roads engineering test data for two Hoytville profiles are given in Table 11.

The relatively high liquid limit of Hoytville soils reflects the moderately high clay content and indicates a low load-carrying capacity. Liquid limit is the percent moisture content at which soil material passes from a plastic to a liquid state. The plastic limit is the percent moisture content at which soil material changes from a semi-solid to a plastic state. The difference between liquid limit and plastic limit is called the plasticity index. The plasticity index gives the range in moisture content at which a soil is in a plastic state. Hoytville soils have a relatively high plasticity index (23%) in the subsoil (Table 11).

The California Bearing Ratio (CBR) test is a measure of the shearing resistance of the soil under controlled density and moisture conditions. Its value is expressed as a percentage of the unit load required to force a piston into the soil, divided by the unit load required to force the same piston to the same depth in a standard sample of compacted, crushed stone. The relatively low values of 7% to 9% for Hoytville soils indicate they have severe limitations when used for highway construction or as a base for airfield runways.

Seasonally high perched water tables, high plasticity, high compressibility, low load carrying capacity, slow runoff, and low percolation rates make the Hoytville soils relatively unfavorable for highway locations, building sites, and septic tank leach beds.

Drainage Characteristics of Hoytville Soils[3]

Tile drainage is practiced extensively on the Hoytville soils. A study of some of the properties which affect tile drainage was made by Taylor, Goins, and Holowaychuk (16), with emphasis on hydraulic conductivity and drainable porosity. The studies were conducted at the Northwestern Branch in 1961.

Some physical properties of the soils of the experimental sites are given in Table 12.

Equivalent conductivity was calculated, utilizing data from rates of water removal obtained from this field study. This conductivity was considered as equivalent to that of a homogeneous soil which, under

[3]The data and interpretations in this section, including Table 12 and Figures 4 and 5, are from a study by Taylor, Goins, and Holowaychuk (16).

TABLE 11.—U. S. Bureau of Public Roads Engineering Test Data for Samples from Hoytville Soil Profiles.

		Moisture Density		CBR Test						
Horizon	Depth	Maximum Dry Density	Optimum Moisture	Molded Dry Density	Specimen Moisture Content	CBR	Swell	Liquid Limit	Plasticity Index	Classification (AASHO)
	(in.)	(lb./cu. ft.)	%	(lb./cu. ft.)	%	%	%			
				Hoytville Soil, Allen County, Indiana						
Ap	0-6	104	21	100.3	20.7	9	1.8	50	19	A-7-5(14)
B21g	12-25	100	22	103.2	21.5	7	1.3	51	24	A-7-6(16)
C	40+	106	20	107.5	19.0	7	1.0	45	27	A-7-6(16)
				Hoytville Soil, Wood County, Ohio						
A	0-7	114	14	—	—	—	—	35	12	A-6(9)
B	7-38	106	17	—	—	—	—	46	27	A-7-6(16)
C	38-96	97	20	—	—	—	—	42	16	A-7-6(11)

TABLE 12.—Bulk Density, 60 cm. Porosity and Hydraulic Conductivity of Hoytville Silty Clay Loam.

Horizon	Bulk Density (g./cc.)	60 cm. Porosity (%)	Hydraulic Conductivity (in./hr.)
Ap	1.29	10.5	.90 to 2.18
B21g	1.45	4.5	.02 to 0.79
B22g	1.54	3.1	.06 to 0.2
B3g	1.60	3.7	.06 to 0.2
C	1.61	—	.06 to 0.2

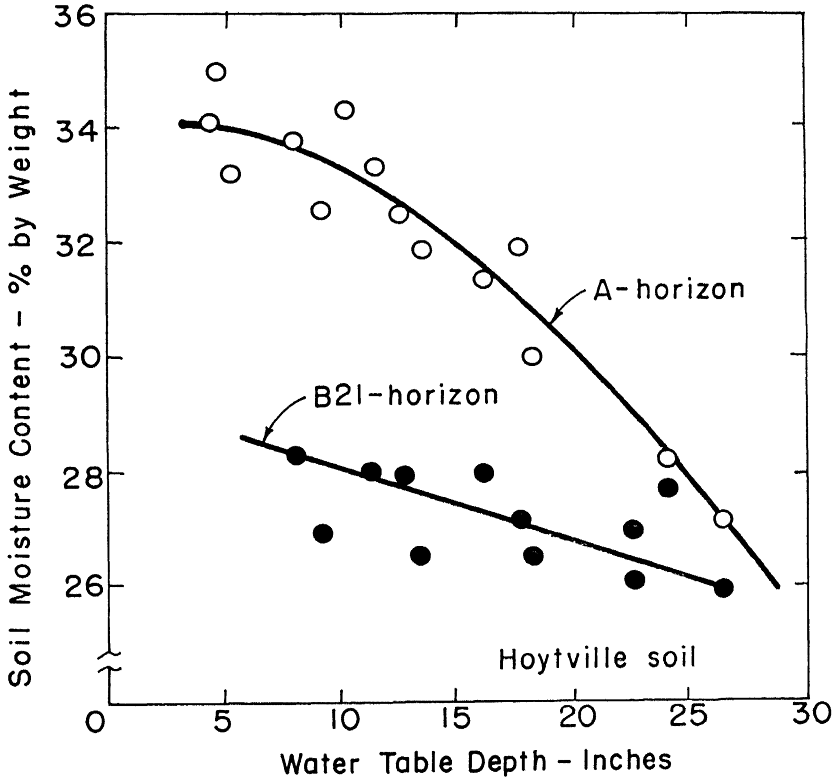

Fig. 4.—Soil moisture contents in Hoytville silty clay loam as a function of water table depth during the third and fourth drawdowns.

comparable water table height at midplane, would yield the same inflow into an open drain as actually measured under field conditions.

Equivalent conductivity for Hoytville soils gave a value of 0.82 inch per hour. This rate is much greater than those predicted by auger hole methods (0.005 inch/hr.) and by criteria based on soil morphological characteristics by O'Neal (10).

The water table depths at the midplane (20 feet) between tile lines for the third and fourth drawdowns are shown in Figure 5. The first and second drawdowns are not reported since they show essentially the same characteristics as the third and fourth drawdowns. The rate of drawdown was quite rapid, particularly during the first few hours. The maximum rate of water removal was approximately 0.4 inch per day. The rate of water removal is a function of the water table depth at the midplane. After the water table subsided to about 18 inches, the rate of drawdown was much slower.

In studying the moisture content of the Ap and B21 horizons sampled at the midplane (20 feet from the tiles), the moisture content decreased from 34% to 26%. This represents a total decrease of 0.8 inch of water in the Ap horizons during drawdown. There was little change in the moisture level of B21g horizons during drawdown.

The field moisture percentages are significantly lower than those obtained by saturating in the laboratory. For example, the saturation

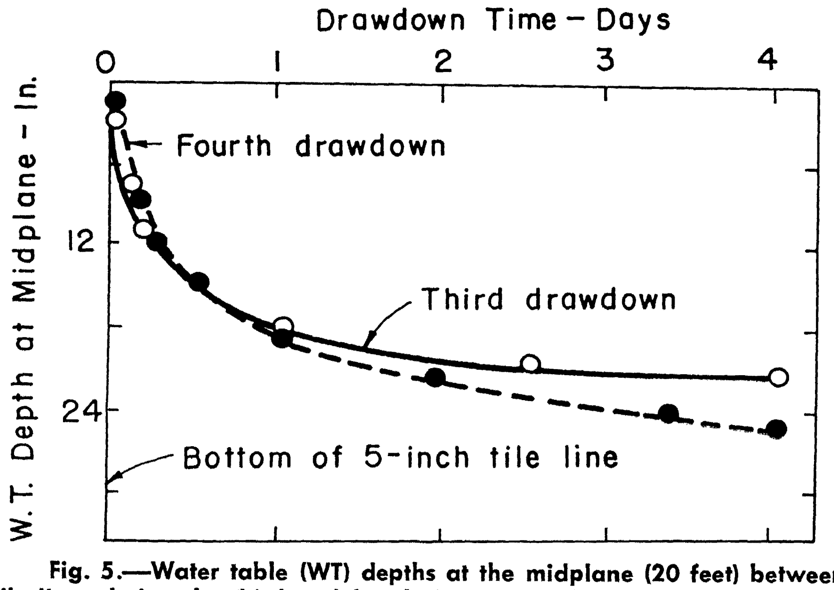

Fig. 5.—Water table (WT) depths at the midplane (20 feet) between tile lines during the third and fourth drawdowns in Hoytville soils.

percentages of the Ap and B21g horizons were 39.6% and 32.8%, respectively, and corresponding values of 34.0% and 28.0% were the highest obtained by field sampling. The lower values from field sampling have been attributed in part to air entrapment within pore spaces.

Effect of Drainage Systems on Crop Yields

The Hoytville soils are potentially productive soils but often produce limited crop yields. They cause management problems due to persistent wetness during the spring planting season. The excess moisture during cool spring weather is caused by the fine soil texture and poor internal and external drainage. If worked while soil moisture is greater than its lower plastic limits, the soil dries into large irregular clods as shaped by tillage tools, causing excessive aeration of the surface layer and a poor seedbed. Waiting for the soil to dry may delay seedbed preparation and planting and subsequently reduce yields. Unless the Hoytville soils are properly drained, excess water may remain on the surface or within the soil well into the growing season.

In 1956, two types of drainage systems were selected by Triplett and Van Doren (17) to be used on Hoytville soils. These two systems consisted of surface drainage only and surface drainage combined with tile drainage. The surface drains, 250 feet apart, consisted of grassed waterways. The ditches had gradients of 6 inches per 100 feet, were 5 feet wide at the bottom, and had 4 to 1 side slopes. Tile drainage was installed on half of the plots at a depth of 3 to 3.5 feet, using a 4-inch diameter clay tile placed on a gradient of 6 inches per 100 feet and spaced at 50-foot intervals.

Tile drainage improved corn yields in 1958 and oat yields in 1959. In the non-tiled area, the variation in yields between plots (Figure 6) was much greater with a less clearly defined mode. To insure positive surface drainage, land forming operations were carried out in 1959. After the 1959-1960 land forming operations were completed, corn yields in 1961 on both tiled and non-tiled areas were approximately the same (Figure 7).

In the Hoytville soil areas, the distribution of rainfall during the months of March, April, and May generally determines the impact of an adequate drainage system in increasing crop production. A properly designed surface drainage system combined with tile drainage has been used with good success by farmers in this area. This drainage system removes excess surface water and internal water rapidly, allowing the soil to warm up and dry out earlier in spring. This results in better aeration, more aerobic microbial activity, and an increase in the availability of plant nutrients.

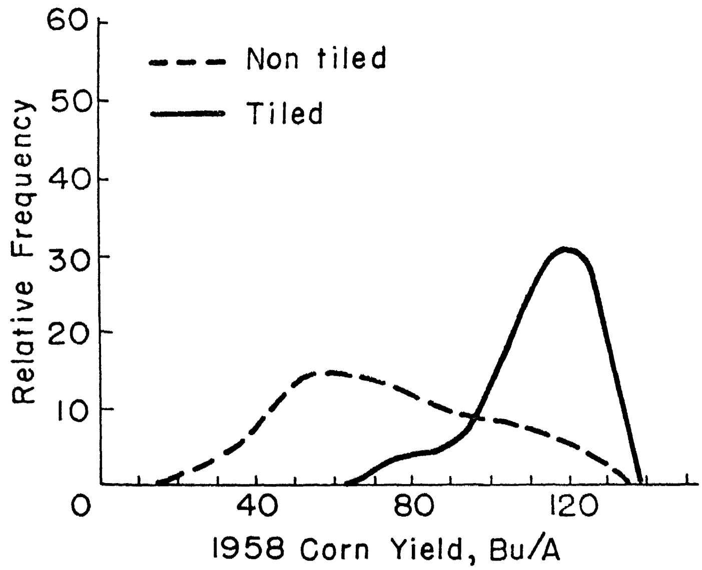

Fig. 6.—Relative frequency of corn yields in 1958 with 384 plots represented for each drainage system.

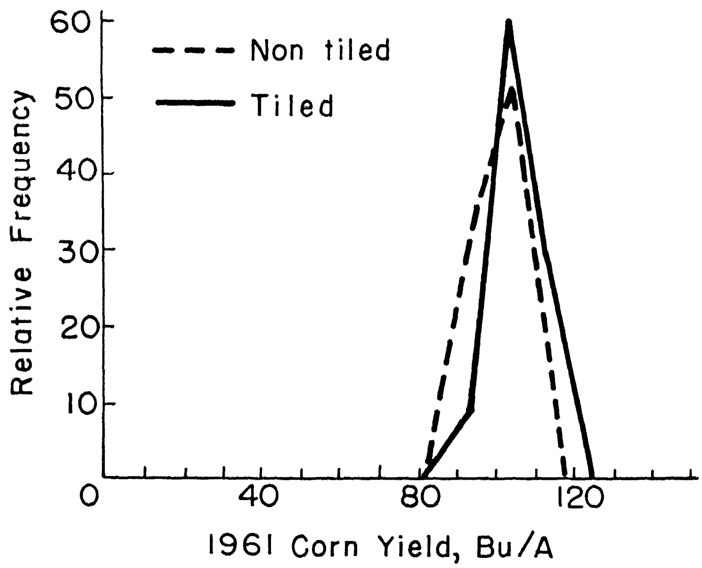

Fig. 7.—Relative frequency of corn yields in 1961 with 180 plots represented for each drainage system.

LITERATURE CITED

1. Baker, F. J., R. L. Meeker, and N. Holowaychuk. 1960. Soil survey of Paulding County, Ohio. USDA-SCS with Ohio Dept. of Natural Res. and Ohio Agri. Exp. Sta. Series 1954, No. 12.
2. Baker, F. J., G. M. Schafer, and N. Holowaychuk. 1960. Surficial materials and soils of Paulding County, Ohio. Ohio J. Sci. 60:365-377.
3. Edwards, W. M., J. B. Fehrenbacher, and J. P. Varra. 1964. The effect of discrete ped density on corn root penetration in a planosol. Soil Sci. Soc. Amer. Proc. 28:560-564.
4. Forsyth, Jane L. 1959. The beach ridges of northern Ohio. Info. Circ. 25, Div. of Geol. Survey.
5. Goldthwait, R. P. 1959. Scenes in Ohio during the last ice age. Ohio J. Sci. 59:193-216.
6. Gordon, R. B. 1966. Natural vegetation of Ohio. Ohio Biol. Survey, Columbus, map.
7. Heffner, R. L., A. R. Brock, R. L. Christman, and D. D. Waters. 1965. Soil survey of Allen County, Ohio. USDA-SCS, with Ohio Dept. of Natural Res. and Ohio Agri. Exp. Sta. Series 1960, No. 24.
8. Jones, J. B., Jr. and O. L. Musgrave. 1963. Fertility status of Ohio soils as shown by soil tests in 1961. Ohio Agri. Exp. Sta., Res. Circ. 118.
9. McLean, E. O. and R. H. Simon. 1958. Potassium release and fixation in Ohio soils as measured by cropping and chemical extraction. Ohio Agri. Exp. Sta., Res. Bull. 824.
10. O'Neal, A. M. 1949. Soil characteristics significant in evaluating permeability. Soil Sci. 67:403-409.
11. Pratt, P. F. and H. H. Morse. 1954. Potassium release from exchangeable and nonexchangeable form in Ohio soils. Ohio Agri. Exp. Sta., Res. Bull. 747.
12. Sampson, H. C. 1930. Succession in the swamp forest formation in northern Ohio. Ohio J. Sci. 30:340-357.
13. Schafer, G. M. and N. Holowaychuk. 1958. Medium- and fine-textured humic-gley soils of Ohio. Soil Sci. Soc. Amer. Proc. 22:262-267.
14. Smeck, N. E. 1966. Genesis of argillic horizons in Celina and Morley soils of western Ohio. M. S. Thesis, The Ohio State University.
15. Soil Survey Staff, USDA. 1960. Soil classification, a comprehensive system. 7th Approximation. U. S. Govt. Printing Office, Washington, D. C.
16. Taylor, G. S., T. Goins, and N. Holowaychuk. 1961. Drainage characteristics of Toledo and Hoytville soils. Ohio Agri. Exp. Sta., Res. Bull. 876.

17. Triplett, G. B., Jr. and D. M. Van Doren, Jr. 1963. Development of a drainage variable facility for soil and crop management studies on a lakebed clay soil. Ohio Agri. Exp. Sta., Res. Circ. 117.

18. Wilding, L. P. and L. R. Drees. 1968. Distribution and implications of sponge spicules in surficial deposits. Ohio J. Sci., Vol. 68, March-April.

19. Wilding, L. P., R. B. Jones, and G. M. Schafer. 1965. Variations of soil morphological properties within Miami, Celina, and Crosby mapping units in west-central Ohio. Soil Sci. Soc. Amer. Proc. 29:711-717.

20. Wilding, L. P., G. M. Schafer, and R. B. Jones. 1964. Morley and Blount soils: A statistical summary of certain physical and chemical properties of some selected profiles from Ohio. Soil Sci. Soc. Amer. Proc. 28:674-679.

APPENDIX

APPENDIX I.—Profiles Evaluated for a Statistical Summary of Hoytville Soil in Ohio.

Site No.	Year Sampled	Comments
AL-S7	1957	Complete information not available
*AL-16	1954	
*AL-22	1954	
AL-33	1954	
DF-1	1954	Too fine (56.2% clay in B12)
DF-S2	1954	No description
HK-24	1960	Mollic epipedon — 13 inches
HK-5	1958	Loam surface
HN-64	1962	Too coarse in C horizon (<35% clay)
HN-65	1962	Too coarse in C horizon (<35% clay)
LG-18	1962	Mollic epipedon — 13 inches
LG-19	1962	Mollic epipedon — > 10 inches
*SA-10	1959	
VW-S1	1956	Underlain by loamy sand
*VW-3	1954	
VW-5	1956	Mollic epipedon — 16 inches
*VW-6	1954	
VW-S7	1956	Mollic epipedon — 18 inches
VW-S8	1954	Stratified profile
*VW-9	1954	
*VW-10	1954	
*VW-12	1954	
VW-13	1954	34% clay in C horizozn
*VW-15	1954	
VW-17	1954	Mollic epipedon — 15 inches
*VW-18	1954	
VW-19	1954	High values and chroma in B
*VW-20	1954	
*VW-21	1954	
VW-26	1958	(10YR 5/6 in B23)
*WD-7	1953	
WD-S9	1952	31% clay in C horizon
WD-S18	1965	Incomplete description and sampling
*WD-19	1954	
WD-25	1954	Incomplete description and sampling
WD-39	1954	(70% clay at 40 inches)
*WD-73	1956	
WD-87	1956	Mollic epipedon — 13 inches
PD-S25	1952-53	Incomplete description and sampling
PD-S26	1952-53	Incomplete description and sampling
PD-S27	1952-53	Incomplete description and sampling
PD-S34	1952-53	Surface color too light-10YR 4/1
PD-S36	1952-53	Incomplete description and sampling
*PD-47	1954	
*Pauding No. 5	1952	
*Paulding No. 6	1952	

*Profiles included in statistical summary.

The following samples were not included in the statistical summary because they were overlooked when the data were organized and evaluaated. However, these profiles meet the criteria as established for the study:

	Year Sampled
WD-84	1956
VW-1	1954
VW-2	1954
VW-7	1954
HN-7	1961

A review of these profile descriptions and physical data indicate no appreciable deviation from means obtained from the 19 profiles summarized.

The State Is the Campus for Agricultural Research and Development

Ohio's major soil types and climatic conditions are represented at the Research Center's 11 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 13 departments on more than 6000 acres at Center headquarters in Wooster, nine branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1918 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Mahoning County Experiment Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Central Branch, Vickery, Erie County: 335 acres

Northwestern Branch, Hoytville, Wood County: 247 acres

Southeastern Branch, Carpenter, Meigs County: 330 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Marietta, Washington County: 20 acres

Western Branch, South Charleston, Clark County: 428 acres